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VISUAL ESTIMATES OF THE TWILIGHT SKY COLOR FROM THE SOYUZ-5 SPACESHIP OBSERVATIONS

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ABSTRACT. Results of a program to determine the twilight halo and color of the twilight sky using the Soyuz-5 satellite in 1969 are described. Results of other similar experiments are discussed.

Optical investigations of the terrestrial atmosphere, performed during /824* the flight of the Soyuz-5 spaceship, included simultaneous photography and spectrophotometry of the twilight halo, as well as visual observations, aimed at determining the evolution of the brightness and of the color of the twilight sky near the horizon. In accordance with this program, visual observations of the twilight halo were performed on 15 January 1969 (2nd and 6^{th} orbits), and on 16 January 1969 (15^{th} orbit). The geographic coordinates of the Soyuz-5 during the visual observations were approximately as follows: 2^{nd} orbit — 30° southern latitude and 157.4° eastern longitude (near the eastern coast of Australia); 6^{th} orbit — 51.69° southern latitude and 147.14° eastern longitude (Auckland Islands); 15^{th} orbit — 4.29° southern latitude and 131.66° eastern longitude (New Guinea area). The Soyuz-5 apogee was

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* Numbers in the margin indicate the pagination in the original foreign text.

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$h \simeq 233$ km. The visual observations preceded a spectrophotometric experiment with the twilight halo, and were performed when the sunset angle beyond the horizon was $\delta_\odot \simeq 3—15°$

The synoptic situation in the subsatellite zone was stable: there were no indications of hurricanes, cyclones, etc. Observations of the altitude evolution and of the brightness of the twilight halo were performed in a cloudless atmosphere (second orbit) and with a solid cloud cover and discontinuous cloud covers, which prevailed during the 6^{th} and 15^{th} orbits, respectively. The visual observations of the vertical color distribution of the twilight halo in a cloudless atmosphere can be summarized in the following manner. The edge of the earth is clearly visible in the form of a dark line. Near the surface of the Earth, the twilight halo displays red-orange tones. With increasing altitude of the observed layer, the color of the halo gradually passes into yellow-orange and yellow shades, with an adjacent narrow dark-blue band with a reduced brightness; this band is at an altitude of approximately 1/3 of the visible halo dimensions. Following immediately the dark-blue band is a range of blue and light-blue colors. This range, occupying approximately 2/3 of the visible dimensions of the halo, displays dark-blue and black-to-violet tones at the boundary with open outer space (black). With the decreasing sunset angle beyond the horizon, the brightness of the halo increases, and the dark-blue band disappears. The color saturation of the tones of the twilight halo goes up.

When the cloud cover is solid, the upper cloud boundary plays the role of the underlying surface. The vertical evolution of the halo cover remains the same as with cloudless atmosphere. However, at the lower portion, the halo displays purple-red and deep-rose shades. The upper edge of the cloud layer is washed out and begins to luminesce when the sunset angle (beyond the horizon) decreases on account of solar light scattering. The brightness of the halo increases noticeably in the lower layers. With discontinuous cloudiness, the color evolution in the vertical direction is the same as indicated above. The breaks in the clouds are red.

This description of the color evolution of the twilight halo differs in /825
certain substantive details from descriptions furnished by other observers. Thus, according to Mme. V. V. Nikolayeva-Tereshkova [1], the lower portion of the halo which displays red-orange and yellow tones passes through a wide whitish band to light-blue, dark-blue and black-to-violet shades. According to the visual observations performed by McDivitt and E. White from the "Gemini-4" spaceship [2], the halo coloration sequence in a vertical direction from the line of the horizon is as follows: red-orange shades, followed by yellow, light blue, whitish, then again light-blue and blue, and finally whitish (wide band).

K. P. Feoktistov [3] observed the following evolution of the color tones of the twilight halo: from red-orange to yellow, blue and whitish, again to blue and whitish, and finally again blue and whitish.

The different descriptions of the twilight halo color in a vertical direction indicate that: 1) During the flights of the "Voskhod-6", "Gemini-4", "Voskhod" and "Soyuz-5" spacecrafts, the specific meteorological conditions in the terrestrial atmosphere obviously were different. Moreover, the sighting geometry of the twilight halo and the magnitude of the sunset angle beyond the horizon also differed; 2) The colorimetric data are a sensitive indicator of the specifics of the vertical atmospheric structure. In a separate contribution [4], the authors compared visual observation results of the twilight sky with colorimetric quantitative data, based upon twilight spectra evaluation, thus leading to a correct analysis of the influence of the atmospheric structure upon the color picture of the horizon.

It should be also kept in mind that the color perception by astronauts is a subjective phenomenon, which does not depend exclusively upon the specific optical characteristics of their vision and general physiological properties of human vision, such as brightness and color adaptation, etc. The investigation of these problems, which is within the competence of

physicians and biologists, is extremely important for the interpretation of colorimetric data, obtained from space. It is highly desirable that specialists in the respective fields perform such investigations in the nearest future.

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